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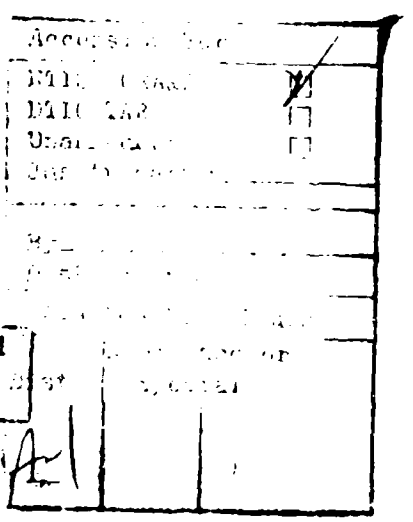

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SYMPATHETIC DETONATION OF 16"/50 HC PROJECTILES

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ABSTRACT

As part of the Naval Explosives Safety Improvement Program (NESIP), a series of tests have been conducted to verify predictions concerning the sympathetic detonability of 16"/50 HC projectiles. Analytical studies could not rule out the possibility of sympathetic detonation. Based on the test results, a reaction probability of eleven percent can be estimated. With this estimate of the reaction probability, it is assessed that the 16"/50 HC projectile (loaded with Explosive D) will not mass detonate.

INTRODUCTION

With the reintroduction of the battleship into the active fleet, questions have been raised about some aspects of the ammunition associated with its 16-inch guns. One specific question which was raised is, "Will 16"/50 HC projectiles mass detonate?"

The 16"/50 round is shown schematically in Figure 1. The projectile empty case weight (including base plug and gas check gasket) is 1720 pounds. The projectile is filled with 154 pounds of Explosive D (Ammonium Picrate). The average wall thickness is 3 to 3 1/2 inches.

Previous NESIP (Naval Explosives Safety Improvement Program) work has investigated the sympathetic characteristics of 5"/54 projectiles loaded with both Composition A-3 and Explosive D.[1] Those loaded with Explosive D failed to detonate even when in contact with a donor projectile; those loaded with Composition A-3 sympathetically detonated, even out to significant separations between donor and acceptor. The same held true for pallets of the ammunition-those loaded with Explosive D do not detonate, those loaded with Composition A-3 do.

The 5"/54, 8"/55, and 16"/50 are a family of HC (High Capacity) shells, which have been loaded with Explosive D. The similarities between these three shells should afford a reliable way to estimate the 16"/50 behavior, based on the 5"/54 and 8"/55 data. A comparison of all three projectiles is presented in Table 1.

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[1]Porzel, F. B., "A Model and Methods for Control of Sympathetic Detonation," Minutes of the Eighteenth Explosive Safety Seminar, Volume II, San Antonio, Texas, 12-14 Sep 1978.

TABLE 1 HC FAMILY OF PROJECTILES

	5"/54	8"/55	16"/50	16" Scaled*	16" Scaled**
Explosive Weight (lb)	7.8	21.3	154	256	171
Total Weight (lb)	78	258	1874	2556	2064
Explosive/Total Mass	0.10	0.083	0.082	0.10	0.083
Case Thickness (in)	0.7	1.6	3.2-3.5	2.3	3.2

*Scaled up from 5" data

**Scaled up from 8" data

According to the NESIP "Action Criterion",[1] explosive sensitivity is yield dependent, via duration and size. Even though a 5"/54 projectile (loaded with Explosive D) was shown to be safe, i.e., would not sympathetically detonate, it cannot be assumed, a priori, that a 16"/50 projectile is also safe. Since a 16" projectile is over three times the width of a 5" projectile, the loading duration increases and the impact pressure required for sympathetic reaction can decrease by a factor of $(5/16)^{1/3}$ for a 16" projectile relative to a 5" projectile. There is also undocumented evidence that an 8" projectile loaded with Explosive D did mass detonate.[2]

Analyses conducted for this study indicated the following:

1. The 16"/50 HC round (loaded with Explosive D) will possibly mass detonate on contact, from either blast or fragments.

2. The 8" round (loaded with Explosive D) is, at best, marginal.

3. The 5"/54 round (loaded with Explosive D) should not detonate.

Because of the prediction that sympathetic detonation was possible, a limited test program was organized and conducted to verify it. The remainder of this report documents the results of that effort.

EXPERIMENTAL PROGRAM

Since the number of assets available was limited, a simple six-shot experimental program was proposed and fielded. Five shots were conducted with one donor and two acceptor warheads on each shot. This experimental arrangement is shown in Figure 2. The spacing between the donor and acceptor

[2]Daugherty, E., (NAVSEA-06H), private communication.

rounds was varied on each shot to cover the range of 0 to 1 charge diameters. Table 2 presents the spacings used on each shot. The sixth shot consisted of a stack of nine rounds in an hexagonal close-pack arrangement. The center round of this stack was detonated. This arrangement is shown in Figure 3. This close-pack arrangement simulates the actual stacking scheme aboard ship.

All 24 projectiles utilized on this program were from existing Navy stock. They had been inspected by the Naval Weapons Support Center (NWSC), Crane, Indiana, and were rejected for fleet use. The rejections were for a variety of reasons--none of which affected the test program. Some were rejected for stuck fuzes, some for damaged rotating bands, and some for stuck base plug.

Each donor projectile was initiated with approximately 1-pound of Composition C-4 placed in the nose fuze well.

The stated purpose of the tests was to determine if 16"/50 HC projectiles can be made to sympathetically detonate. To address that question, several techniques were used:

1. Witness plates beneath each round.
2. Flash panels to measure the fragment velocity from the acceptor rounds.
3. High speed photography.
4. Airblast.

RESULTS

Table 2 summarizes the results of all the shots. On the first five shots, none of the acceptor projectiles reacted. Figure 4 shows a before and an after of one of the witness plates. Where the donor was located, there is a hole in the plate. Where the acceptors were located, there are no marks or indentations on the plate.

All of the acceptor rounds were thrown considerable distances--up to 431 feet in one case. The location of the acceptor projectiles for all the shots were surveyed. These are shown in Table 3. In addition, they are indicated in a projectile map--Figure 5. (It should be noted here that all measurements are with respect to ground zero).

Each acceptor round was damaged--though there were no case failures or penetrations. In each case, the rotating bands were stripped off. There was evidence of fragment impacts, case flattening, and case deformation, but no case penetrations.

The last shot studied two effects--the effect of confinement and the effect of interaction between rounds. On this shot, six rounds were recovered intact, one appeared to detonate or violently react and one appeared to break apart or deflagrate.

TABLE 2

16"/50 HC SYMPATHETIC DETONATION TEST PROGRAM AND RESULTS

Shot Number	Spacing (inches/diameters[+])	Results
2097	0	0/2 reacted
2098	0	0/2 reacted
2099	4,8 (.25, .50)	0/2 reacted
2100	1,2 (.06, .12)	0/2 reacted
2101	12, 15 1/4 (.75, .95)	0/2 reacted
2102		1/8 detonated* 1/8 deflagrated** 6/8 no reaction

*Or violent reaction

**Low order reaction

[+]Indicated by numbers in parenthesis

At the location of the donor, a hole was punched through the witness plate. At the location of Acceptor I, there was a deformation and tearing of the plate--indicating some type of reaction (Projectile I was never located). The case of Acceptor G was recovered in two pieces. Explosive D remained in the lower portion of the case. Post shot investigation showed evidence of Explosive D on the ground below the trajectory of Acceptor G. (This evidence indicated that G reacted in some manner--but with much less violence than did Acceptor I).

Before detonation, there was a 4' x 4' x 4" steel plate, weighing approximately 2 tons lying on the ground adjacent to ground zero. This plate was thrown approximately 150 feet by the detonation. Two of the acceptor projectiles were thrown over 1000 feet, with one thrown over 1600 feet. The pre- and post-shot locations of each of these projectiles are indicated in Figure 6 and Table 3.

DISCUSSION

The original question which prompted this work was "Will the 16"/50 HC projectiles mass detonate?" The apparent answer is NO, they will not. If you consider that there were a total of 18 possible acceptor projectiles on all six shots, and that only two reacted in any way, an estimate of the probability of reaction is 2/18 or 11%. (NOTE: Because of the limited number of shots, this is, at best, a crude estimate).

In order for a reaction to be self-sustaining, i.e., propagate, the reaction probability must be at least 25% (P_D^3 greater than 1/N, where N is the number of nearest neighbors). Since our estimate (11%) is less than this, the reaction chain is not self-sustaining--i.e., the reaction would die out.

The only reactions observed were those on the nine-projectile stack. This may be due to several reasons: (1) The effects of the confinement produced by the adjacent projectiles leading to some type of focusing or jetting along specific directions or (2) probability--the limitations produced by the small sample size.

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[3]Porzel, F. B., "Technology Base of the Navy Explosives Safety Improvement Program," Minutes of the Nineteenth Explosive Safety Seminar, Los Angeles, CA, 9-11 Sep 1980.

TABLE 3 FINAL POSITIONS OF ACCEPTOR PROJECTILES

SHOT NUMBER	PROJECTILE DESIGNATION*	RANGE (ft)	EVELATION (ft)	BEARING (0)
2097	L	202	18	110
	R	170	39	273
2098	L	184	15	104
	R	251	51	288
2099	L	431	19	114
	R	213	45	283
2100	L	145	17	93
	R	277	29	305
2101	L	105	7	94
	R	122	21	274
2102	A	1609	-49	39
	B	1286	-79	336
	C	530	46	314
	E	151	23	81
	F	405	68	300
	G (upper)	515	-33	132
	G (lower)	872	-50	119
	H	1015	-52	126
	PLATE	160	38	269

*L is the projectile on the left, looking toward ground zero
R is the projectile on the right, looking toward ground zero.

FIGURE 1. 16"/50 HC PROJECTILE

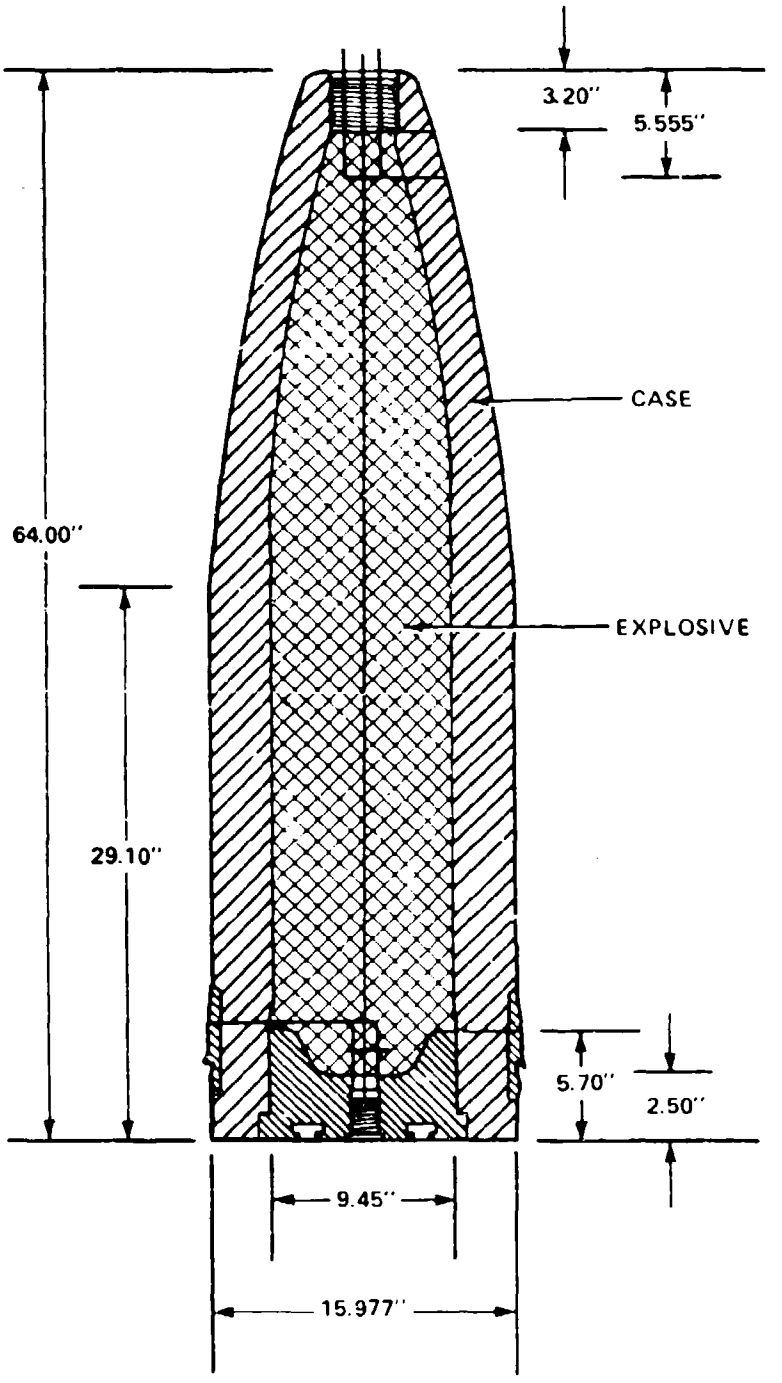
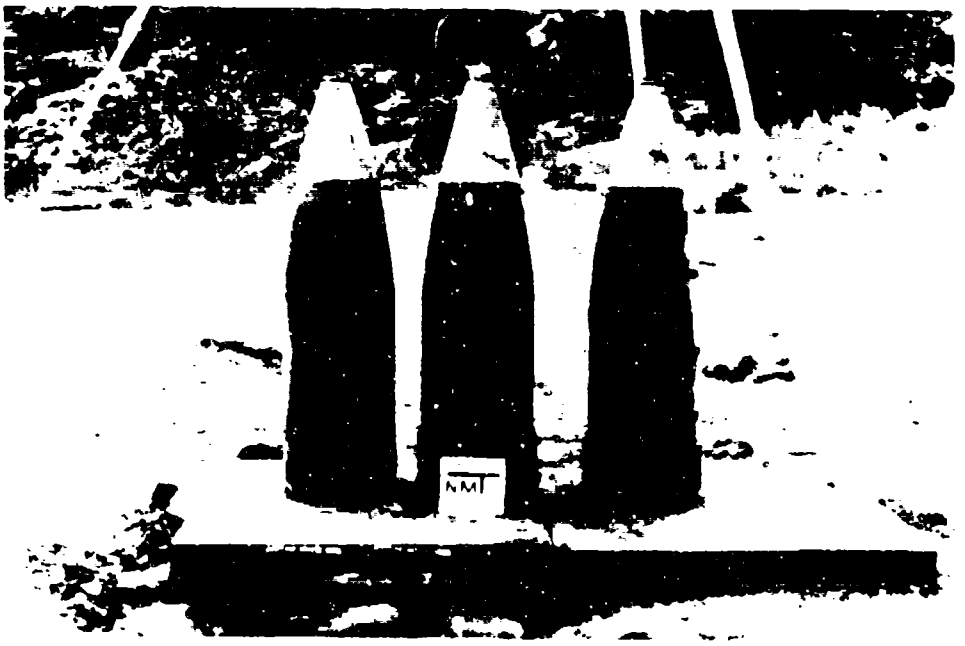


FIGURE 2. SINGLE-ROUND SYMPATHETIC DETONATION TEST ARRANGEMENT



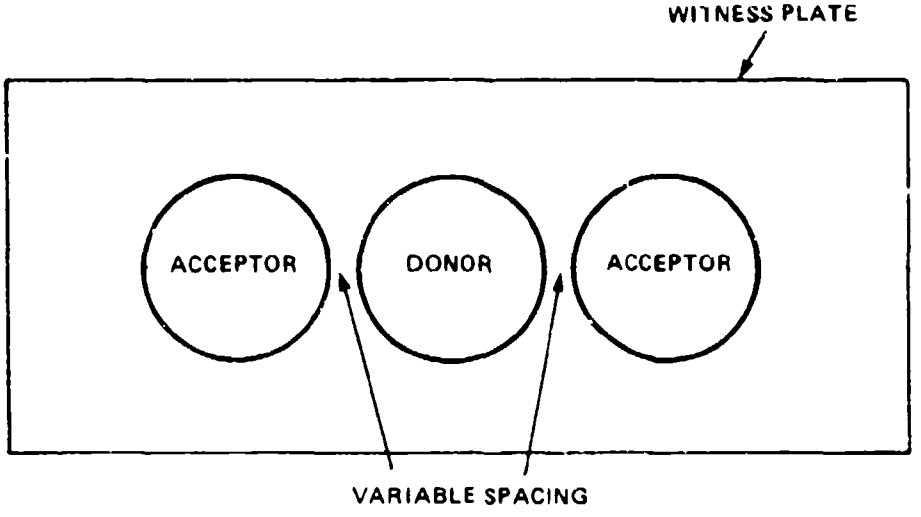


FIGURE 3. NINE-PROJECTILE TEST ARRANGEMENT

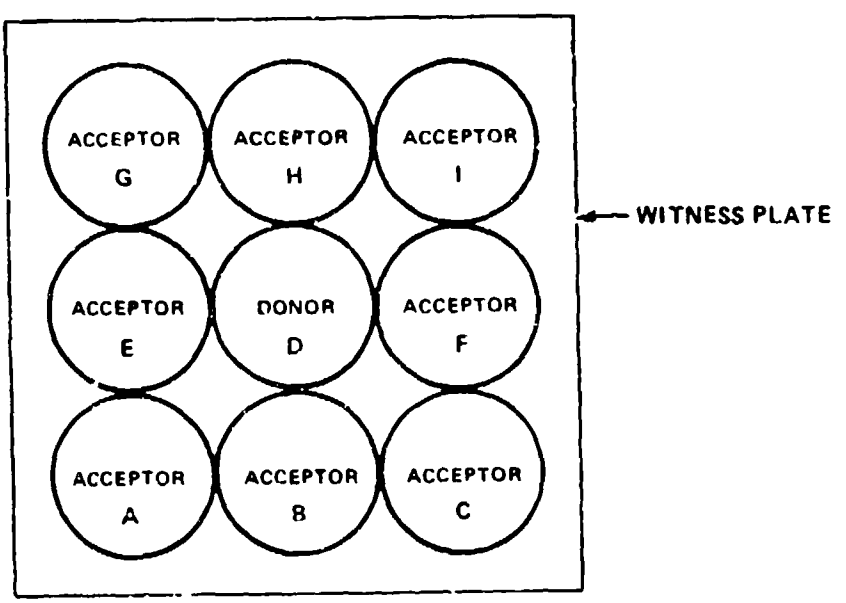


FIGURE 4. BEFORE AND AFTER— SYMPATHETIC DETONATION TEST

BEFORE

AFTER

FIGURE 5. PROJECTILE MAP FOR SHOTS 2097–2101

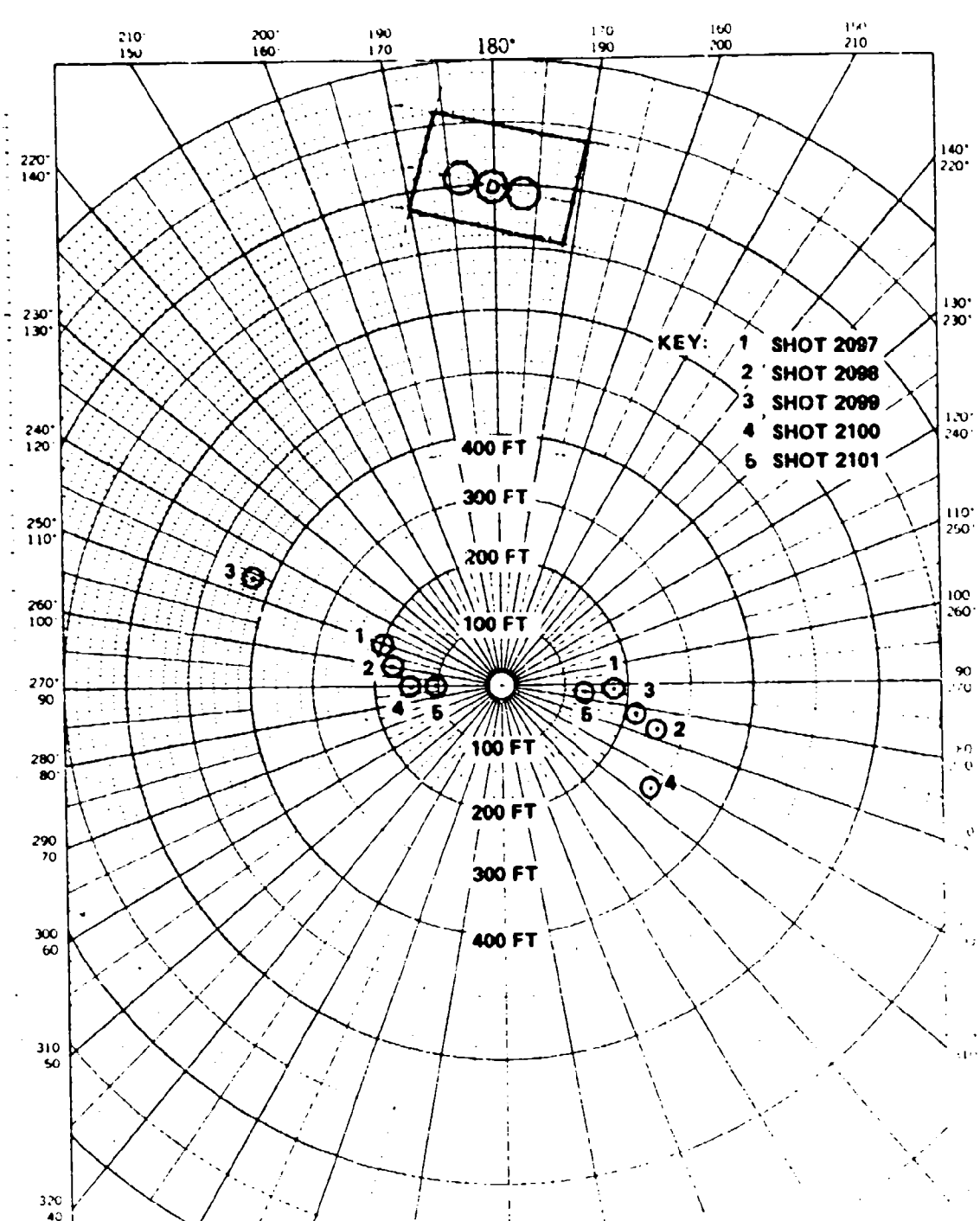


FIGURE 6. PROJECTILE MAP FOR SHOT 2102